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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H03H

A2

(11) International Publication Number: WO 00/65713

(43) International Publication Date: 2 November 2000 (02.11.00)

(21) International Application Number: PCT/EP00/03273

(22) International Filing Date: 12 April 2000 (12.04.00)

(30) Priority Data:
99201234.4 22 April 1999 (22.04.99) EP

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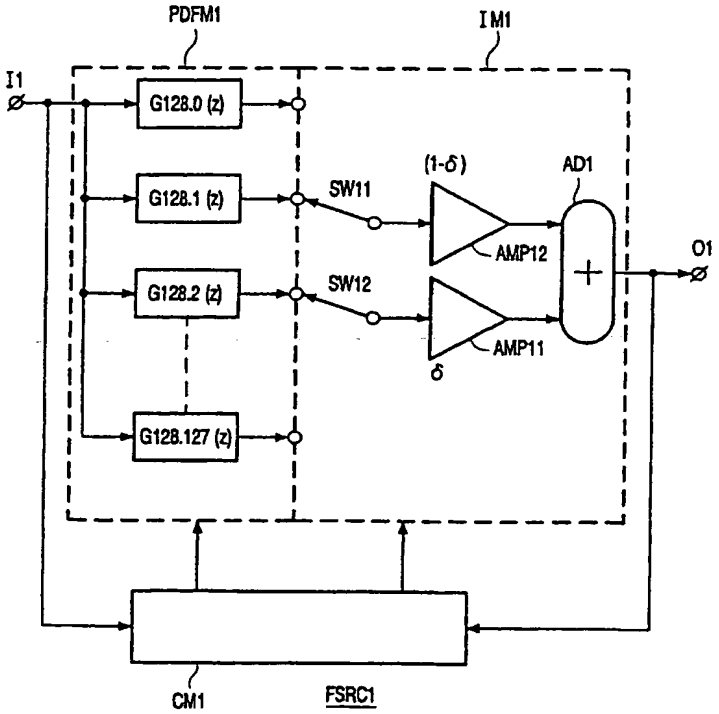
(81) Designated States: CN, JP, KR, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: SAMPLE RATE CONVERTER

(57) Abstract

Sample rate converters are known, and are used to convert a signal with a first sample rate (sampling frequency) into a signal with a second sample rate (sampling frequency). To obtain a flexible sample rate converter with sampling frequencies that are not known beforehand, until now only sample rate converters with very high intermediate sampling frequencies are known. The invention provides a flexible sample rate converter, which is able to handle unknown input and output sampling frequencies. This is achieved by using polyphase decomposition filter means in combination with interpolation means.



BNSDOCID: <WO_____0065713A2_I_>

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BNSDOCID: <WO_____0065713A2_I_>

Sample rate converter

The invention relates to a sample rate converter.

Sample rate converters are known in the art and are used to convert a digital signal with a first (input) sample rate (sampling frequency) into a digital signal with a second (output) sample rate (sampling frequency). The sample rate can be increased (up-converter) or decreased (down converter).

Such sample rate converters are required when processing signals of a system using a first sampling rate in a system, which uses a second sampling rate. For example compact disc uses 44.1 kHz, digital audiotape uses 48 kHz and satellite broadcasting uses 32 kHz.

If the ratio between the original frequency and the target frequency is not a whole number, known sample rate converters need a very high intermediate conversion frequency. Further a multiplicity of circuits and filters use multiple stages and the number of sets of coefficients that are necessary grows in proportion to the intermediate frequency. Further more these methods do not allow different target frequencies to be selected using a single circuit.

In US-A-5,349,548 and US-A-5,625,581 non-integral delay circuits are described that can be used in such a sample rate converter.
From US-A-4,748,578 a sample rate converter is known which has a selectable output frequency, but with a high intermediate frequency.

From US-A-5,559,513 a sample rate converter is known that tries to solve the complexity of known sample rate converters by using first an up-conversion with a factor N (the required resolution of the output signal) creating an intermediate signal, followed by a linear interpolation between two adjacent samples of the intermediate signal based on the ratio between the input and the output sample rate.

A disadvantage of this known sample rate converter is that the linear interpolator that is used herein has to calculate all samples at the high sample rate. Further a moving time averager is used to supply a sum signal to the linear interpolator.

An object of the invention is to overcome the disadvantages of the prior art and further to obtain a sample rate converter which both can be used as up-converter and as down-converter using the same circuit.

To this end a first aspect of the invention provides a sample rate converter as defined in claim 1.

The sample rate converter of the present invention has as advantages that it is only necessary to calculate the samples that are necessary instead of calculating all the samples as the prior art sample rate converters do. Further a moving time averager is not necessary.

This is achieved by realizing that by using the combination of polyphase decomposition filter means and interpolation means a very efficient flexible sample rate converter can be obtained.

A considerable smaller number of calculations per second are needed and a considerable smaller number of coefficients have to be calculated and stored.

Further the sample rate converter is able to handle arbitrary input and output sampling frequencies.

The only thing that has to be known beforehand is the required suppression of the so-called mirror spectra and the necessary relative bandwidth. On the basis of this information the filter-coefficients are chosen and these coefficients can be used for both the up-sampler as the down-sampler.

An embodiment of a sample rate converter according to the invention comprises the features of claim 2.

By adding an auxiliary up-converter in front of the series-arrangement, the operation of the flexible sample rate converter is further improved. By using the auxiliary up-converter the up-conversion can be splitted in more stages, which improves the performance.

An embodiment of a sample rate converter according to the invention comprises the features of claim 3.

An embodiment of a sample rate converter according to the invention comprises the features of claim 4.

By using the measures of the invention it is possible to use the flexible sample rate converter for both up- as for down-conversion.

Further the filters are beforehand determined on the basis of the required image suppression (mirror spectra) and necessary relative bandwidth.

Further embodiments are described in the other dependent claims.

The invention and additional features, which may optimally be used to implement the invention to advantage, will be apparent from and elucidated with reference to the examples described below hereinafter and shown in the figures. Herein shows:

Figure 1 a block schematic example of a sample rate converter as an up-converter,

Figure 2 a functional example of a flexible sample rate converter as an up-converter,

Figure 3 a blocks schematic example of a sample rate converter as a down-converter, and

Figure 4 a functional example of a flexible sample rate converter as a down-converter.

Figure 1 shows a first example of a flexible sample rate converter FSRC1 embodied as an up-converter according to the invention having an input I1 and an output O1. This flexible sample rate converter comprises a series-arrangement of polyphase decomposition filter means PDFM1 and interpolation means IM1.

Further the flexible sample rate converter comprises control means CM1 that control the operation of the polyphase decomposition filter means PDFM1 and the interpolation means IM1.

In this context flexible means that the actual ratio between the input and output sampling frequencies does not have to be known in advance. Instead, the required amount of suppression of the images created in the conversion process has to be known. These images may lead to unwanted aliasing. This information and the relative bandwidth are needed to design the interpolating filters.

The polyphase decomposition filter means PDFM1 comprises in this example 128 polyphase branches (G128,0 (z)-G128,127 (z)). In this example the outputs of the polyphase branches are coupled to switches SW11 and SW12 of the interpolation means IM1. The interpolation means further comprises a first and a second amplifier AMP11 and AMP12, whereby the amplifier AMP11 amplifies the received signal with a factor δ and whereby the amplifier AMP12 amplifies the received signal with a factor $(1-\delta)$.

The outputs of the amplifiers are coupled to an adder AD1 that supplies the summed signal to the output O1 of the flexible sample rate converter FSRC1.

The control means CM1 determines the value of δ. Further the control means determines which pair of samples has to be calculated. , in case of linear interpolation.

Figure 2 shows a functional example of a flexible sample rate converter FSRC2 as an up-converter. The flexible sample rate converter comprises in this example a series-arrangement of first up-conversion means UCM21, first filter means FM21, second up-conversion means UCM22, second filter means FM22 and down conversion means DCM2. By splitting the up-conversion in two stages with filter means in between the efficiency of the sample rate converter is improved. The transition band of the first filter means can be chosen very narrow and the transition band of the second filter means can be chosen very broad.

Figure 3 shows a practical example of a flexible sample rate converter as a down-converter FSRC3 having an input I3 and an output O3. This flexible sample rate converter comprises a series-arrangement of interpolation means IM3 and polyphase decomposition filter means PDFM3 having Ko branches (GKo,0 (z)-GKo,Ko-1 (z)). Further the flexible sample rate converter comprises control means CM3 for controlling the operation of the interpolation means and the polyphase decomposition filter means.

The flexible sample rate converter according to this example (as down-converter) is the transposed version of the flexible sample rate converter (as up-converter, see figure 1), in this way it is possible to use the same flexible sample rate converter for both up- and down-conversion by interchanging the input I3 and the output O3. The man skilled in the art is well aware of the changes to be performed to obtain the transposed circuit.

Figure 4 shows a functional example of a flexible sample rate converter as a down-converter FSRC4, whereby between an input I4 and an output O4 a series-arrangement of up-converting means UCM4, first filter means FM41, first down-conversion means DCM41, second filter means FM42 and second down-conversion means DCM42 is placed. The factors can be chosen as required, whereby Ko and K1 are fixed integers and L<=Ko*K1. The first filter means FM41 can be implemented as a linear interpolator.

The invention has been described on the basis of some examples. The man skilled in the art will be well aware of a lot of variations falling within the scope of the invention.

Instead of the described linear interpolation it is also possible to use a higher order interpolation in case this is required. For example to obtain a more precise estimation of the sample to be interpolated.

Further one or more up-conversion stages can be added, for example to lower the up-conversion factor of the other stages.

CLAIMS:

1. Flexible sample rate converter comprising a series-arrangement of polyphase decomposition filter means and interpolator means, whereby one side of the series-arrangement is coupled to an input of the flexible sample rate converter for receiving an input signal with a first sampling frequency and the other side of the series-arrangement is coupled to an output for supplying an output signal with a second sampling frequency, and the flexible sample rate converter comprises control means for controlling the polyphase decomposition filter means and the interpolation means.

2. Flexible sample rate converter as claimed in claim 1, characterized in that the flexible sample rate converter comprises an auxiliary up-converter with an up-conversion of at least two, whereby in operation the sampling frequency or frequencies used in the flexible sample rate converter are lower than or equal to the highest frequency of the input and output sampling frequencies multiplied with the auxiliary up-conversion factor.

3. Flexible sample rate converter as claimed in claim 1, characterized in that the flexible sample rate converter is an up-converter whereby the input is coupled to the polyphase decomposition filter means and the output is coupled to the interpolation means.

4. Flexible sample rate converter as claimed in claim 1, characterized in that the flexible sample rate converter is a down converter whereby the input is coupled to the interpolation means and the output is coupled to the polyphase decomposition filter means.

5. Flexible sample rate converter as claimed in claim 1, characterized in that the interpolation means are linear interpolation means.

6. Flexible sample rate converter as claimed in claim 1, characterized in that the interpolation means is higher order interpolation means.

7. Flexible sample rate converter as claimed in claim 1, characterized in that the polyphase decomposition filter means comprise 128 polyphase branches whereby only those samples that have to be interpolated are determined under control of the control means.

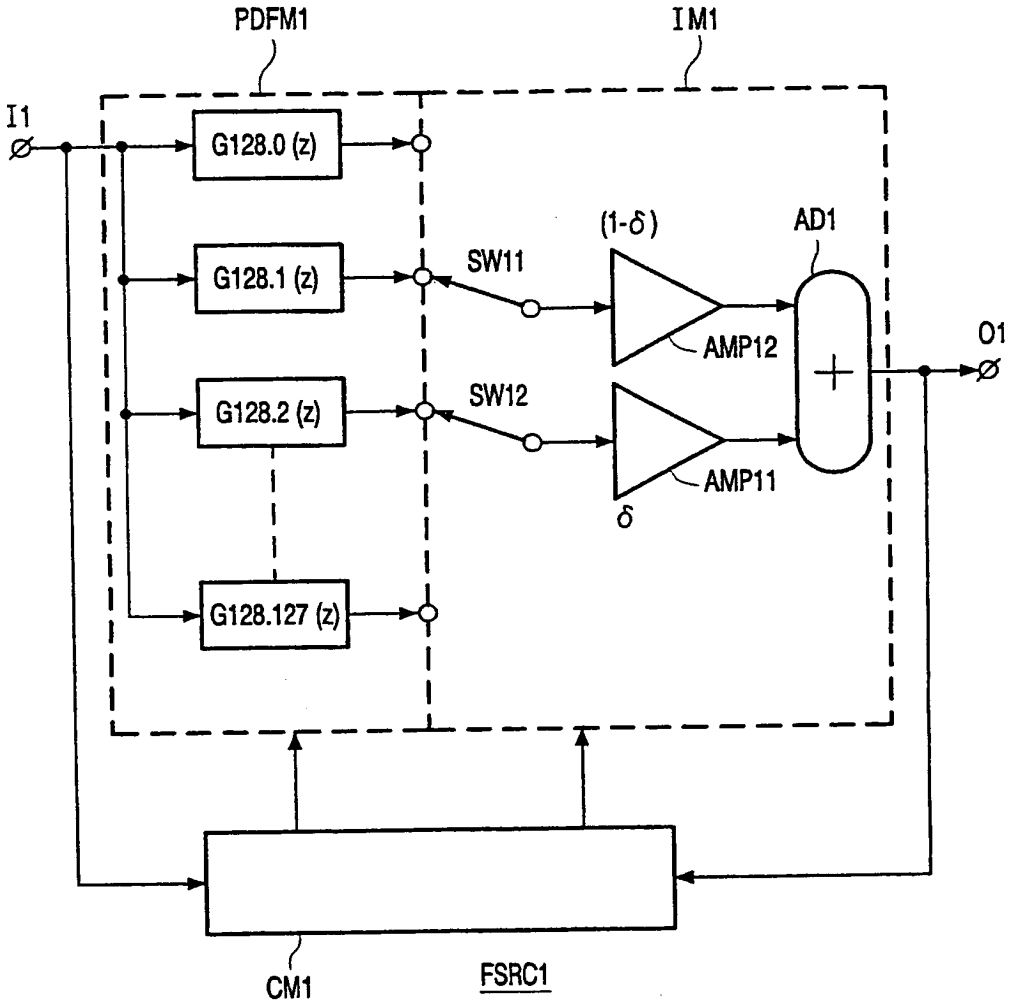
PDFM1
IM1
I1
G128.0 (z)
G128.1 (z)
G128.2 (z)
G128.127 (z)
SW11
SW12
(1-δ)
δ
AMP12
AMP11
AD1
O1
CM1
FSRC1

FIG. 1

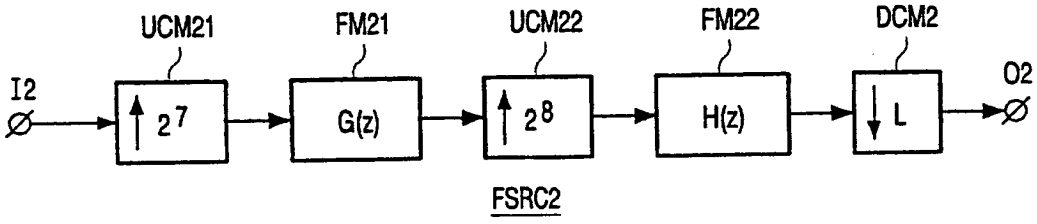
UCM21
FM21
UCM22
FM22
DCM2
I2
2 7
G(z)
2 8
H(z)
L
O2
FSRC2

FIG. 2

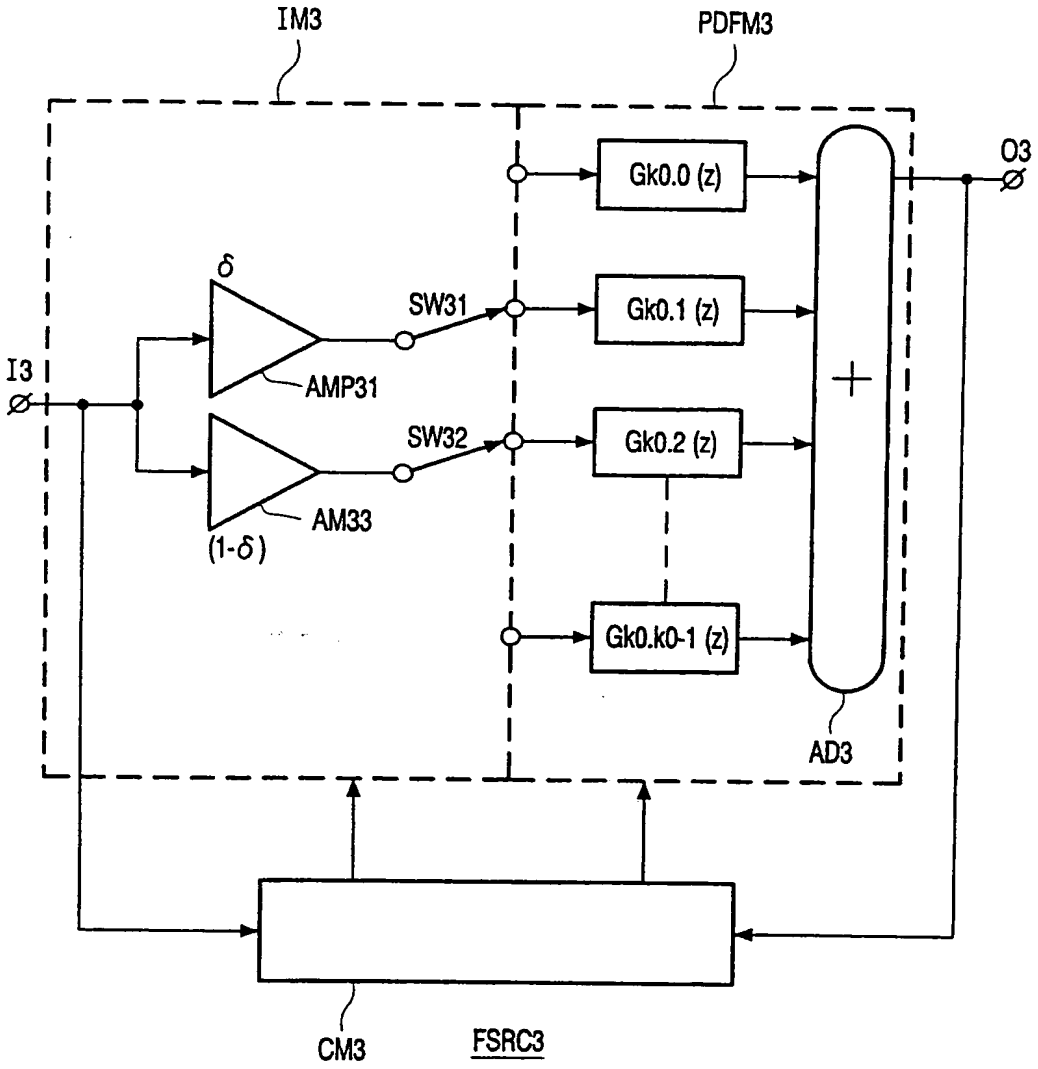
IM3
PDFM3
O3
Gk0.0 (z)
δ
SW31
Gk0.1 (z)
I3
AMP31
SW32
Gk0.2 (z)
AM33
(1-δ)
Gk0.k0-1 (z)
AD3
CM3
FSRC3

FIG. 3

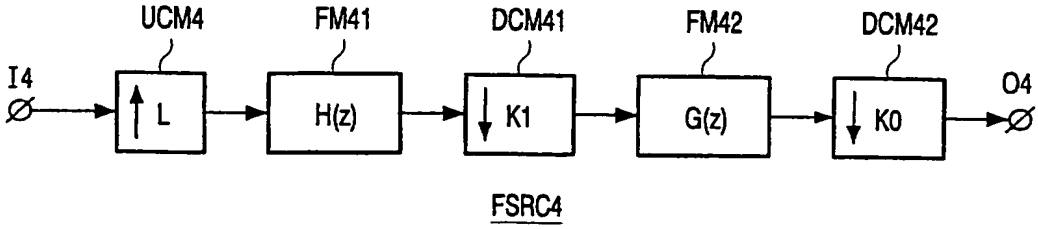
UCM4
FM41
DCM41
FM42
DCM42
I4
L
H(z)
K1
G(z)
K0
O4
FSRC4

FIG. 4

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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 November 2000 (02.11.2000)

PCT

(10) International Publication Number
WO 00/65713 A3

(51) International Patent Classification[7]: H03H 17/06, 17/02

(21) International Application Number: PCT/EP00/03273

(22) International Filing Date: 12 April 2000 (12.04.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
99201234.4 22 April 1999 (22.04.1999) EP

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(74) Agent: SCHOENMAKER, Maarten; Internationaal Octrooibureau B.V., Prof Holstlaan 6, NL-5656 AA Eindhoven (NL).

(81) Designated States *(national)*: CN, JP, KR.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*

[Continued on next page]

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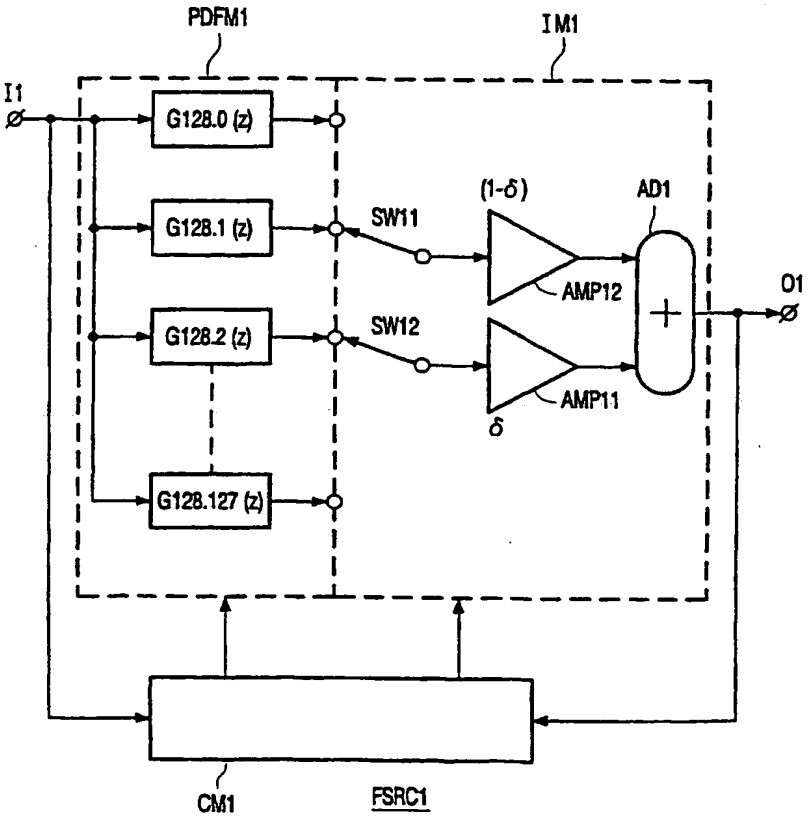

(57) Abstract: Sample rate converters are known, and are used to convert a signal with a first sample rate (sampling frequency) into a signal with a second sample rate (sampling frequency). To obtain a flexible sample rate converter with sampling frequencies that are not known beforehand, until now only sample rate converters with very high intermediate sampling frequencies are known. The invention provides a flexible sample rate converter, which is able to handle unknown input and output sampling frequencies. This is achieved by using polyphase decomposition filter means in combination with interpolation means.

WO 00/65713 A3

(88) Date of publication of the international search report:
12 July 2001

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INTERNATIONAL SEARCH REPORT

Inte... Application No
PCT/EP 00/03273

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H03H17/06 H03H17/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	the whole document	2,7
A	WO 98 34346 A (SHARP KK) 6 August 1998 (1998-08-06) page 8, line 18 -page 11, line 7; figure 2	4

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Date of the actual completion of the international search	Date of mailing of the international search report
10 August 2000	18/08/2000

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		GB 2271905 A,B	27-04-1994
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WO 9834346 A	06-08-1998	NONE	

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